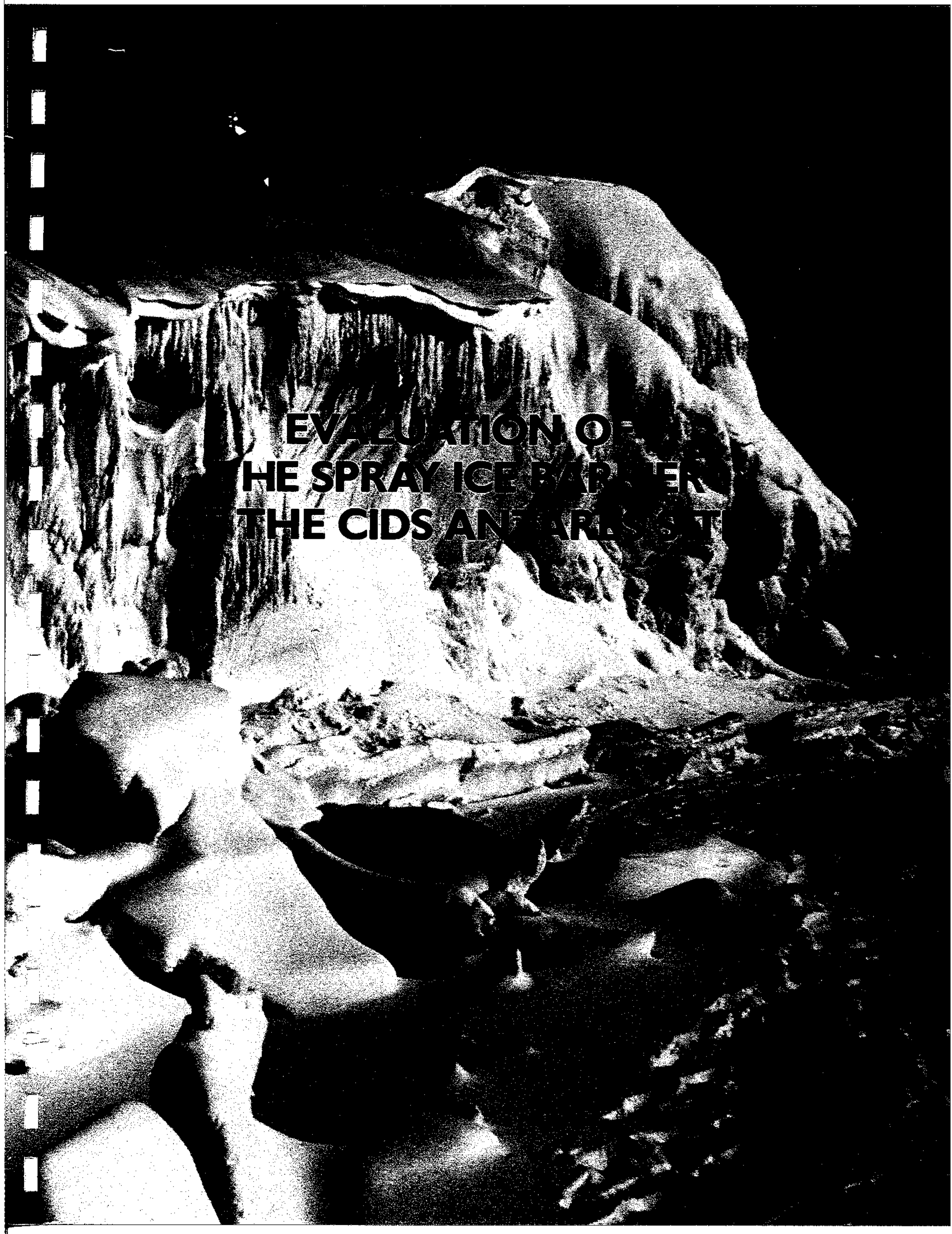
EVALUATION OF
THE SPRAY ICE BARRIER
THE CIDS ANTARES SITE

EVALUATION OF THE SPRAY ICE BARRIER AT THE CIDS ANTARES SITE DURING 1985 USING TIMELAPSE PHOTOGRAPHY

FINAL REPORT
February 1988

REVISED
August 1988

Submitted to:

The Cold Regions Research and Engineering Laboratory

EXXON Production Research Company

The Mineral Management Service

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EXECUTIVE SUMMARY

During November 1984 a spray ice barrier was constructed by EXXON Company U.S.A. around three sides of Global Marine Drilling Company's Concrete Island Drilling Structure (CIDS), (Jahns and Petrie, 1986). As one means of monitoring the effectiveness of the structure, EXXON Production Research Company deployed six time-lapse cameras around the CIDS. The cameras were at the CIDS Antares location from mid-January through mid-August, when the CIDS was moved from the Antares location.

The six cameras were initially located on the spray ice barrier. Each camera was set up so that it could record sea ice movements and how the movements affected the spray ice barrier. The cameras remained at their locations on the spray ice barrier until early June.

With the approach of breakup in June, the cameras were removed from the barrier and redeployed on the CIDS itself. With the relocation of the cameras, the emphasis changed from monitoring the manner in which the barrier protected the CIDS to how the barrier reacted during the open water season. The cameras were left in place on the CIDS until it was moved in mid-August.

The cameras used for the monitoring of the CIDS barrier were two 16mm Bolex, H16EL cameras and four Automax Model GS-2 cine/pulse cameras. The different format cameras were selected primarily for their operating characteristics, especially their ability to operate under the harsh conditions of Arctic winters. To insure that the cameras operated properly, each camera was enclosed in a specially designed heated enclosure.

During the course of the monitoring program, 12,800 feet of 35mm film and 6,400 feet of 16mm film were exposed. The interval between frames ranged from eight minutes for the 35mm film to one minute for the 16mm cameras. A total of 204,800 individual 35mm images and 256,000 16mm images were recorded for analysis. To reduce the large amount of film to manageable form, the developed film was transfered to a one-inch video master tape and simultaneously to one-half-inch VHS format tapes. The one-inch master video tape is used as the primary storage medium. The one-half-inch tapes are used to carry out the photogrammetric analysis.

The spray ice barrier was constructed during the closing months of 1984. The time-lapse cameras were not deployed until January 25, 1985. Thus information on ice conditions from the formation of the barrier through January were not recorded. At the time the cameras were installed, there were ice pile-ups against the spray ice barrier on the northwest side of the CIDS and also on the eastern side. Through the winter monitoring period from January to May, no ice movements detectable to the cameras were recorded. It is possible that some low amplitude (one- to five-meter) ice movements took place during this period that could not be detected by photogrammetric analysis using the equipment available.

At the end of May and into June, changes started to take place in the ice surrounding the spray barrier. These changes consisted of the formation of melt ponds on the ice surface and a noticeable change in the texture of the ice. On June 8, 1985, the cameras were moved from their locations on the spray barrier to positions on the CIDS to record the breakup of the sea ice, and the dissolution of the barrier.

During the summer monitoring period a great deal of ice activity took place around the CIDS. The breakup of the sea ice took place, and the spray ice barrier underwent significant melting and intermittent periods when large blocks calved from the barrier. By the time the CIDS was moved from the Antares location on August 17, 1988, a large portion of the barrier had been removed. A detaled analysis and chronology of the sea ice breakup around CIDS and the manner and timing of the breakup of the spray ice barrier accompanies this report. A narrative videotape illustrating the nature of the breakup of both the sea ice and the barrier also accompanies this report.

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INTRODUCTION

The purpose of this investigation is to examine the behavior of the spray ice barrier constructed around Global Marine's Concrete Island Drilling Structure (CIDS) during the closing months of 1984. The purpose of the spray ice barrier was to provide protection to the CIDS against sea ice movements.

The design, construction methods and purpose for constructing the spray ice barrier are described in United States Patent Number 4,523,879 which was issued to R. Finucane and H. Jahns and assigned to EXXON Production Research Company on June 18, 1985. In this patent, Finucane and Jahns speculate that variously configured spray ice structures can be used for containing oil spills, protecting offshore structures from wave damage, stabilizing large areas of mobile ice sheets, and protecting structures from mobile ice and other natural forces.

As a means of monitoring the spray ice barrier EXXON Production Research Company commissioned a program to monitor the spray ice barrier using six timelapse cameras. During the initial monitoring period from January to June the timelapse cameras were deployed on and around the barrier. During the service period from June to August, the cameras were removed from the barrier and repositioned at various locations on the CIDS.

In general very little activity took place on and around the ice barrier during the initial winter monitoring period. From the time the cameras were moved onto the CIDS in June until the beginning of August, deterioration of the barrier was detected. Ablation of the barrier from atmospheric factors and erosion of the barrier due to the action of the ocean on the barrier were the causes of this deterioration.

At the beginning of August the erosion accelerated and the barrier continued to disintegrate. At the time the CIDS was moved in mid-August of 1985 much of the ice barrier had either eroded or been washed away by wave action.

The work carried out in this study was conducted under an agreement between EXXON Production Research Company, the Cold Regions Research and Engineering Laboratory and Polar Alpine Inc. Under the terms of this agreement EXXON Production Research Company has made available the film data collected when the ice barrier was in place. The Cold Regions Research and Engineering Laboratory provided funding for the data analysis and Polar Alpine Inc. carried out the analysis and compiled the information into this report.

Accompanying this report is a videotape that illustrates the events of primary interest in terms of the barrier deterioration. The video is intended to complement the written report.

No specific information was available regarding the construction of the barrier or any other type of monitoring that was conducted. Where we have commented on barrier construction we have referenced publicly available information.

BARRIER CONSTRUCTION

The details of the construction of the spray ice barrier at the CIDS site are proprietary to EPR. However, it is reasonable to assume that the techniques utilized in its construction are similar to those described in U.S. Patent 4,523,879 (1). Jahns and Petrie (2) have also described the construction of the spray ice barrier around the CIDS in there 1986 Offshore Technology Conference paper.

A spray ice barrier is constructed by spraying water into the air where some portion of the water freezes and falls to the sea ice surface as granular ice. The size of the ice grains and the density of the accumulated mass is dependent on a number of factors. Using the relatively simple technique described in the patent, the quality and quantity of the spray ice produced is primarily a function of the quantity of contaminants in the water used and the air temperature at the time the spray ice is formed.

As the spray ice accumulates on the natural sea ice, the weight of the spray ice depresses the ice sheet. Spraying is continued until the natural ice sheet and the spray ice are grounded. Grounded spray ice is less susceptible to being displaced by ice movements. The grounding of the sea ice and spray ice takes place when the weight of the overburden equals the buoyant force of the submerged material from the surface to the sea floor. To provide protection against ice movement an additional amount of material must be added above sea level.

In their patent, Finucane and Jahns do not provide any information regarding the amount of spray ice required to protect an offshore structure using spray ice.

In their promotional literature for the Glomar Beaufort Sea I, Global Marine Drilling Company provides information on the water spray system used to build the spray barrier. At the time the spray ice barrier was constructed three Svenska skumslackning water cannon were located on three corners of the Beaufort Sea I. Each of the four water cannons is rated at 10,600 gallons per minute (gpm). Water is supplied to the water cannons by three Gould pumps.

The primary pump is a Gould deepwell turbine pump operated at 880 rpm which delivers 21,500 gpm and is driven by a CAT D399 diesel engine. In addition to the primary pump two Gould 16x18-inch 10,600 gpm centrifugal pumps driven by a CAT D399 diesel engine are also used. Although not explicitly stated, it would appear that the deep-well turbine pump is used as a feed pump for the two centrifugal pumps which feed directly into the water cannons.

The spray ice barrier formed around the Beaufort Sea I in late 1984 had a horseshoe shape with the open end of the horseshoe facing south. Figure 1, which is reproduced from the Finucane and Jahns patent shows an artist's rendition of a spray ice barrier being constructed around a drilling barge. The representation of the spray ice barrier, the drilling barge and the construction detail are similar to the spray ice barrier actually constructed around the Beaufort Sea I, including the opening left at the south end of the structure.

Figure 2, which is also reproduced from the Finucane and Jahns patent, shows a profile view with a cross-section of a spray ice barrier. The cross-section in this diagram may be the inventors' concept of what a cross-section would look like.It should be noted that the subsea profile of the spray ice barrier presented by Finucane and Jahns in Figure 2 is not in static equilibrium.

METHODS AND TECHNIQUES

Cameras

The primary instruments of data collection in this program were six timelapse cameras. Two of the cameras were Bolex H16EL 16mm cameras and four were Automax Model GS-2 cine/pulse 35mm cameras. The different format cameras were selected primarily due to their operating characteristics. Operating under Arctic conditions places a great deal of stress on the comparatively delicate camera equipment. Only a few types of cameras can be operated with minimum difficulty under these conditions.

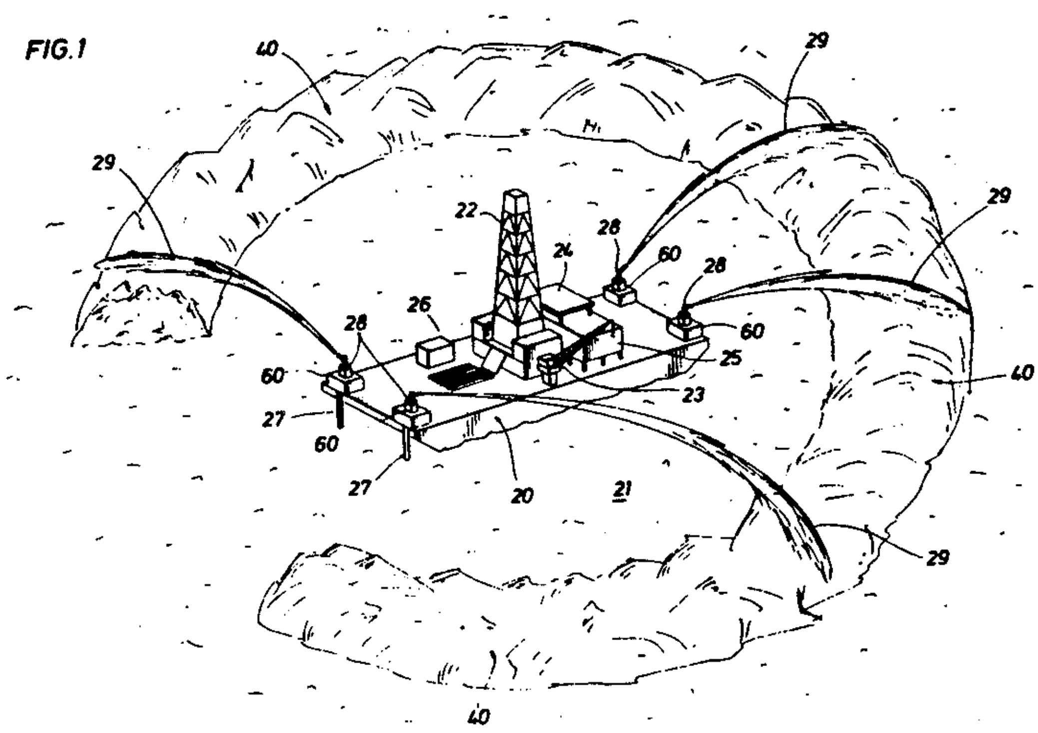


Figure 1. A drawing of a spray ice barrier being constructed around an offshore drilling structure. This figure is taken from U.S. Patent 4,523,879.

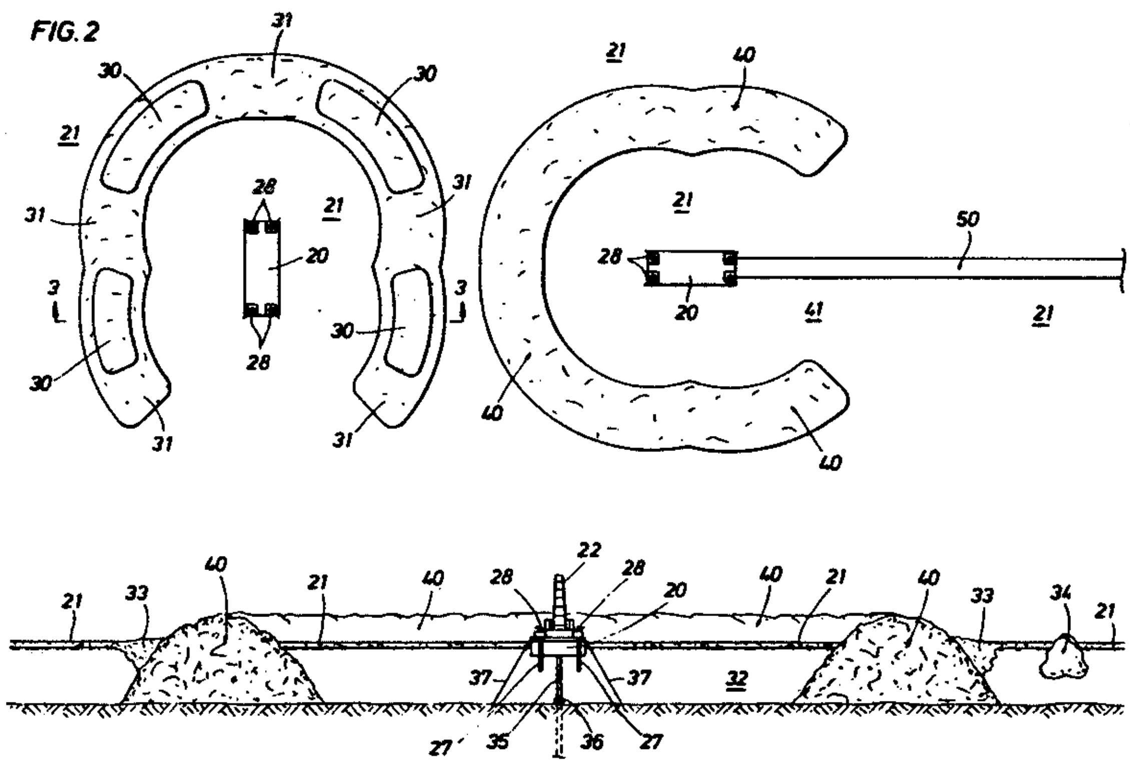


Figure 2. A cross-section of the spray ice barrier shown in Figure 1. Note the subsea profile presented here. Figure taken from U.S. Patent 4,523,879.

35mm Automax Camera

The 35mm Automax cameras have been used in a number of investigations over the past few years and have been found to be reliable. The basic camera system consisted of an Automax model GS-2 camera. Each of the 35mm cameras was fitted with a 400-foot capacity Mitchel film magazine. With the 400 feet 35mm film magazine, 6,400 individual frames can be exposed.

The lens used with the 35mm cameras was a Nikkor 24mm, f/1.8 fixed focal length lens. The lens was fitted with a Photomatrix Corporation Apex-B automatic exposure control. The exposure control regulated the lens aperture to take into account the changing light conditions throughout the daily filming interval.

The 24mm Nikkor lens provided wide-angle viewing for obtaining maximum coverage of the viewing field.

16mm Bolex Camera

The second type of camera used during this program was a 16mm Bolex H16EL camera. The two Bolex cameras were provided with 400-foot Bolex film magazines, which allowed 16,000 frames of film to be exposed. The Bolex cameras were equipped with Kern Vario-Switar 16-to-100mm zoom lenses. The Vario-Switar lens is controlled internally by a galvanometer-driven iris control unit.

The zoom lens feature on the Vario-Switar allowed us to change the focal length of the lens, enabling us to select the appropriate focal length setting in the field. Because of this capability, and the smaller format of the 16mm film compared to the 35mm film, the Bolex cameras could be used to obtain telephoto views.

Intervalometers and Light Sensors

The 16mm cameras were controlled by modified Bolex remote control units. Each of the units was equipped with a light sensor that turned the cameras off at night. The Bolex remote control units allowed the interval between frames to be varied from 0.5 seconds to 999.5 seconds. The modification of these units is required to override the digital electronic circuitry so that the total 16,000 frames of film can be exposed as opposed to the 9,999 that are allowed by the factory-engineered model.

The Automax cameras were controlled using intervalometers built by the Polar Research Laboratory. These intervalometers allowed framing intervals of 1, 2, 4, or 8 minutes to be used. The Automax cameras were operated with light sensors designed and built by Nanotech Corporation.

Camera Enclosures

Both of the camera types, although reliable, are subject to the problems associated with delicate equipment. Because the cameras are precision instruments and require a great deal of care, they must be housed in enclosures that provide a suitable operating environment in which the temperature is maintained above plus ten degrees Fahrenheit.

The enclosures have evolved over several years from large, bulky systems into relatively compact units that can be transported easily and can be mounted on towers or in other precipitous places.

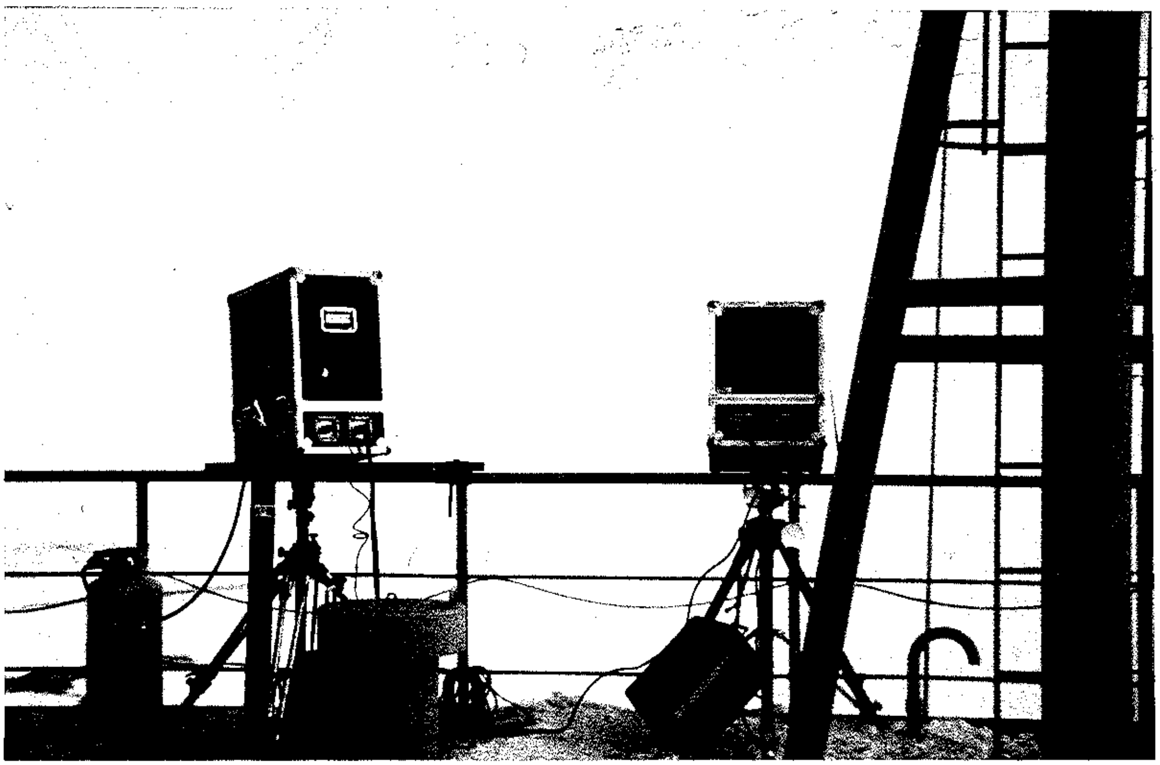
The enclosures consist of two parts: an upper camera chamber and a lower heater chamber. The two chambers are sealed off from each other to prevent moisture given off by the heater from affecting the camera. Heat is transferred by a heat pipe into the chamber. Both chambers are well insulated to retain as much heat as possible.

Photograph 1 shows two camera enclosures located on the CIDS. This installation is typical of the camera installations deployed on the CIDS.

Camera Locations

During this program two different types of camera locations were used. When the cameras were deployed on January 26, 1985, five of the cameras were placed on the spray ice barrier and one was placed in the sea ice rubble on the northwest side of CIDS. During this deployment period, which lasted from January until June, the cameras were directed to view the periphery of the spray ice barrier. In June the location of the cameras was changed from locations on the spray ice barrier to locations around CIDS.

The purpose of the first part of the deployment period (from January to June) was to observe how the spray ice reacted as the natural sea ice moved against it. The primary purpose of the second phase of the deployment was to monitor how the spray ice barrier reacted to the summer breakup of the sea ice and open water conditions, and to gather information on the actual breakup of the barrier itself.



Photograph 1. An example of the camera placement on CIDS showing the camera enclosures and associated hardware.

Photograph 2 is an oblique aerial view of the CIDS and the spray ice barrier. The cameras are designated as C1 through C6 on this photograph. Table 1 below gives the viewing azimuth and other data pertaining to the camera locations.

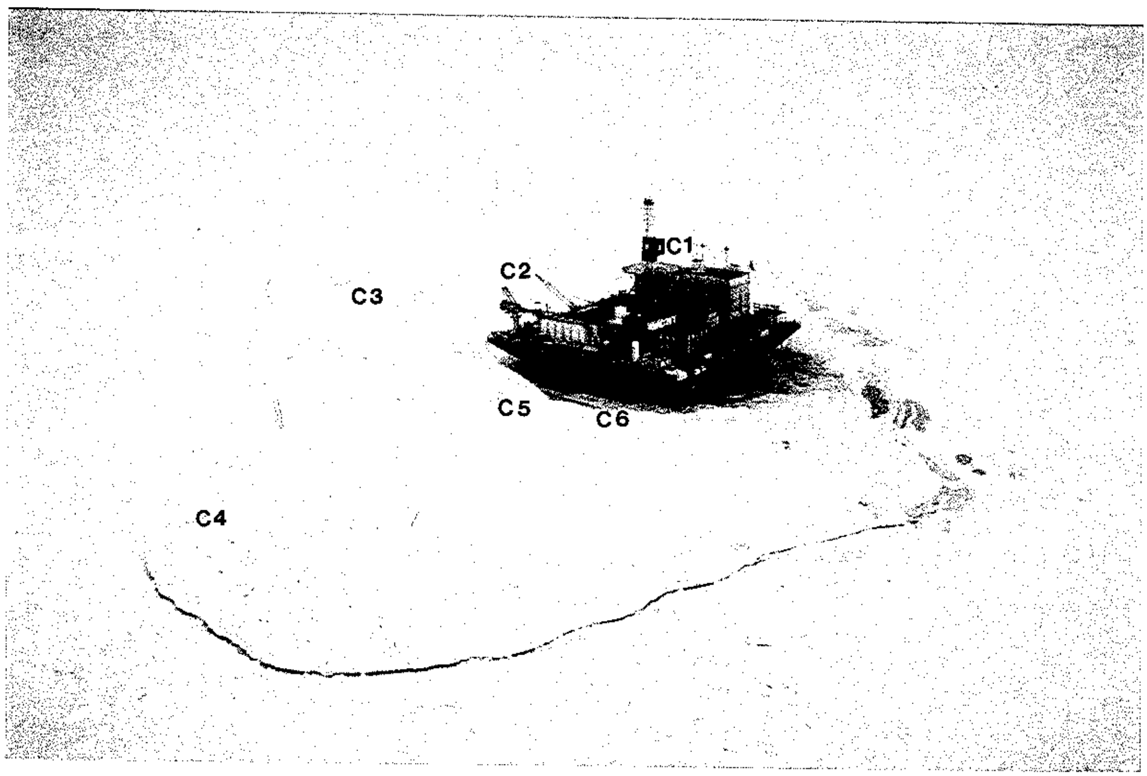
TABLE I. Camera deployment data for the period from January to June 1985. The elevations are given in feet above sea level and the framing rates are presented as minutes between frames. NA indicates that the data was not available.

CAMERA	AZIMUTH ° True	DEPRESSION ANGLE (degrees)	ELEVATION (feet)	FRAMING INTERVAL (minutes)
1	123	1.5	62	2
2	078	3.0	55	3
3	323	4.0	NA	8
4	070	4.0	23	2
5	318	NA	66	3
6	083	4.0	55	2

In Table I above, the depression angle is the angle measured between the the horizontal (true horizon) and the camera axis. The framing interval is the time in minutes between successive exposures.

In general, during the winter the cameras were deployed on local high points on the spray barrier around CIDS. Camera 5 on the west side of CIDS at 66 feet above sea level was at the highest elevation. Camera 4, at an elevation of 23 feet, was located in the sea ice rubble field on the northeast side of the CIDS and not on the barrier itself. As indicated, these cameras remained in place on the spray ice barrier through the winter. On June 8, 1985 the cameras which were located on the spray ice barrier at various locations around CIDS were removed from the barrier.

When the cameras were removed from the barrier they were relocated at various locations on the CIDS. Figure 3 is a schematic representation of where the cameras were located.



Photograph 2. Aerial view of CIDS and the spray ice barrier looking toward the east. Note the large rubble pile on the northwest side and the section of barrier that was sheared off. Cameras locations are indicated by identifiers C1-C6.

The cameras are designated as C1 through C6 on Figure 3. The points designated as F## are the location of surveying flags that were located on the ice barrier and on the natural sea ice.

Table II below provides the specifics of the camera deployment on the CIDS. This information is similar to that described in TABLE I. To avoid confusion regarding the camera numbering system the camera identifications for the summer deployment are designated as 1', 2', etc.

TABLE II. Camera deployment data for the period from June to August, 1985. The elevations are given in feet above sea level and the framing rates are presented as minutes between frames.

CAMERA	AZIMUTH ° True	DEPRESSION ANGLE (degrees)	ELEVATION (feet)	FRAMING INTERVAL (minutes)
1'	360	6.0	119	8
2'	078	9.0	106	8
3'	265	11.0	106	3
4'	108	15.0	60	8
5'	115	17.5	47	3
6'	173	1.5	20	8

To obtain an overall view of summer ice conditions, three of the six cameras were deployed at high points on the CIDS structure. Camera 1' was located above the helideck at an elevation of 119 feet. This camera provided a view looking directly north across the main deck and out toward the barrier. The primary view from this position was a scene of the sea ice conditions to the north of the barrier and the southern (inboard) side of the barrier itself.

Cameras 2' and 3' were both located on top of the crew quarters on the CIDS at elevations of 106 feet. Camera 2' was directed to look along an azimuth of 78° to the east-northeast.

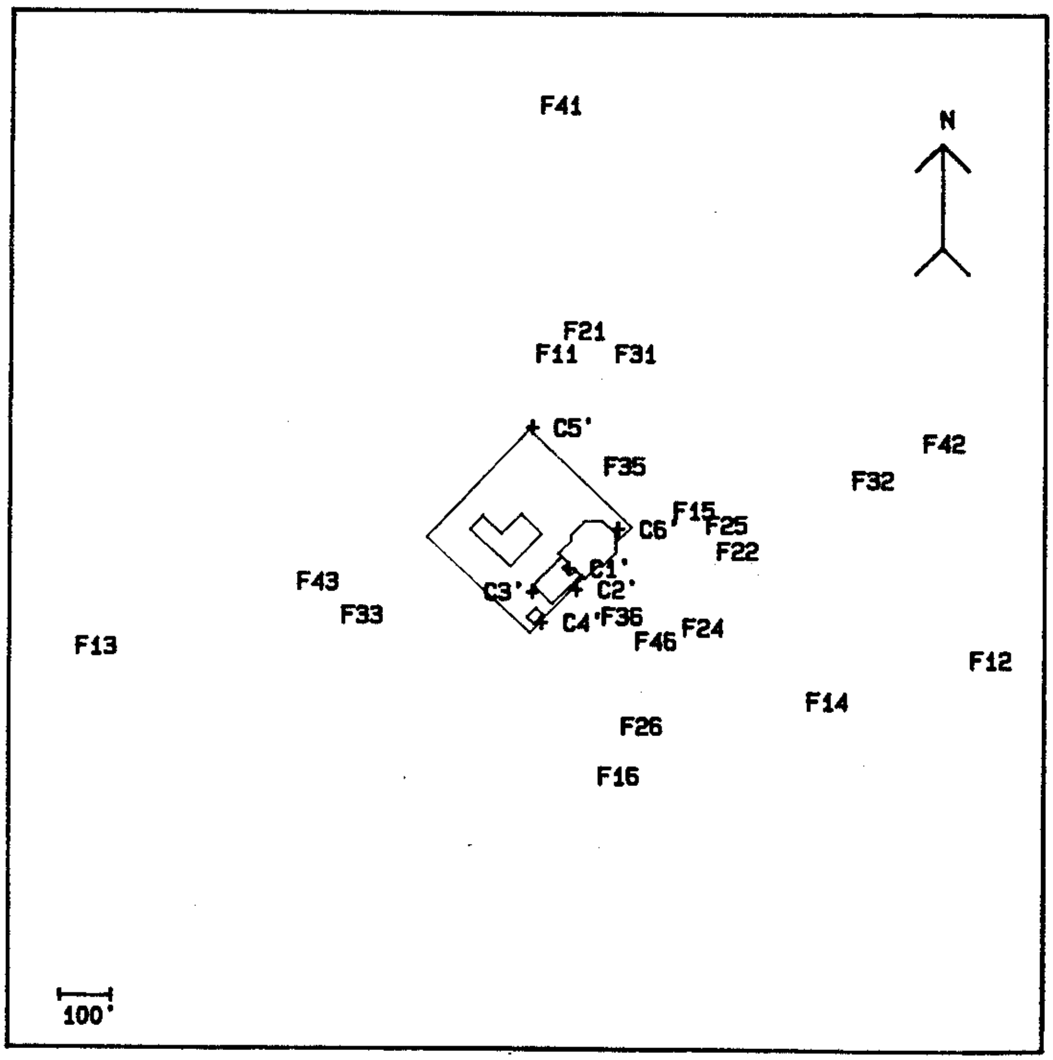


Figure 3. Camera locations on the CIDS and the initial location of the survey flags placed on the ice to verify pixel coordinates. C# indicates camera locations and F# indicates flag locations.

This camera provided a good overall view of the eastern flank of the barrier. Camera 3' was also located at an elevation of 106 feet on top of the crew quarters and was directed to photograph scenes along an azimuth of 265° or nearly WSW. Camera 3' was directed so that it looked at the southwest flank of the spray barrier.

Camera 4' was located on the southern edge of the CIDS on top of the tank heating units at an elevation of 60' above sea level. This camera was directed to photograph along an azimuth of 108°, and like camera 2' viewed events taking place on the southeastern flank of the spray ice barrier.

Camera 5' was placed on the main deck of the CIDS at the most northerly point at an elevation of 47 feet. This camera was directed to look easterly along the northeastern edge of the structure. Photograph 3 was taken from camera 5' and shows the view from the camera and also the flags used for survey control.

Camera 6' was located at an elevation of 20 feet above sea level on the catwalk below deck on the eastern edge of the CIDS. This camera was directed to photograph along an azimuth of 173°. Cameras 2',4', and 6' viewed the same general area of the barrier on the eastern and southeastern and southeastern side of the CIDS from different elevations. Cameras 1', 3' and 6' provided non-overlapping views of different sectors of the barrier.

Filming with the cameras located on the CIDS started on June 9 for cameras 1', 2' and 4' while cameras 5' and 6' started filming on June 10. Camera 3' was not activated until July 10 and Camera 5' was deactivated July 10.

Site Visits

Film changes and general maintenance were performed approximately once per month. The initial installation of the cameras took place at the CIDS site Jan. 25 through 28. Four additional trips were made to the CIDS site to service the cameras at the winter locations. These visits took place in February, March, April and May. During the visit to the CIDS site June 8 through 12 the cameras were relocated from positions on the barrier to locations on the CIDS itself. The cameras were serviced again on July 10 and again on August 5. The spray ice barrier monitoring program was terminated on Aug. 17 when the CIDS was moved from the Antares prospect to the Orion prospect.

ANALYSIS AND DATA REDUCTION

Timelapse photography is an ideal method for the study of ice activity. During this program, events that occurred over extended time periods and too slowly to be observed in real time or "first hand" were viewed between 3,500 and 14,000 times the rate at which they actually occurred. At this rate, a great number of events can be rapidly observed. Because they happen slowly, these events are recorded on many frames. As a result, the resolution of the event (in time) is clear enough to allow for an analysis of the dynamics of the ice activity.

The rate at which the events are speeded-up is a function of the framing interval, which is adjusted to maximize the number of frames exposed (and therefore resolution of the event) within the approximately 30-day service interval. The calculation to determine the framing interval to be used is based on the length of time the camera will operate each day and the total number of frames to be exposed.

The data collected on the films were analyzed on two levels. The initial analysis was primarily qualitative. The films were examined for general ice and weather conditions and the sea state. Each of the films was catalogued, events of interest noted and the corresponding frame numbers recorded. These data are presented in tabular form in Appendix A.

The second level of analysis was quantitative. This consisted in the first phase of the program of tracking the changes at the boundary of spray ice barrier and the sea ice. The second phase of the program concentrated on the dissolution of the barrier and tracked changes in the barrier itself.

During the course of the program, 12,800 feet of 35mm film and 6,400 feet of 16mm film were exposed. This produced over 204,800 individual 35mm images and 256,000 16mm images for analysis. Analyzing this amount of film requires methods and techniques that allow the film to be rapidly viewed, and important features noted and catalogued. The system currently in use provides this capability.

The technique for reducing the large amount of film to a managable form is as follows: After the film is developed, it is transferred to a one-inch master videotape. Simultaneously, two 1/2-inch VHS format videotapes are made. The one-inch master video is the primary storage medium, and is only used for obtaining duplicate tapes. On one of the 1/2-inch tapes, a numbered window is written onto the tape so that each frame of transferred film is assigned a number.

This number is visible on the video screen when the tape is played.

To obtain a one-to-one correspondence between the video fields and the individual frames of film, the film-to-tape transfer was run at the rate of 29 frames per one second of video playing time.

Once the film has been transferred to videotape, the analysis is conducted electronically. The transfer to videotape allows the video image to be run on a SONY SMC-70G computer, greatly facilitating photogrammetric measurements. Using a light pen, the X and Y pixel coordinates of points of interest on the screen are identified. Once pixel coordinates of ice features are determined, scale factors are applied and locations are calculated. The videotape and computer system also display photograph frame numbers so that an accurate record of photograph time and ice events can be assembled.

In general the six timelapse cameras were positioned to provide high oblique terrestrial photographs of the barrier around the CIDS. In photographic terms, a high oblique photograph is one in which the optical axis of the camera is tilted from the vertical so that the horizon is visible. Its scale varies along the azimuth, but is constant along lines parallel to the horizon. Mounting the cameras so they have a slight depression angle allows measurements to be made over all but the most distant areas in each camera's field of view.

The scale for the photographs is obtained by marking and surveying points on the ice and by using the geometric equations that govern the photograph. Reference 2 provides details on the fundamentals of making photogrammetric measurements.

From experience we have found that to insure the accuracy of measurements and confidence in our results, surveying is necessary. The photogrammetric equations require an accurate measurement of the distance from the optical center of the photograph to the apparent horizon. Due to the shallow camera depression angle, the low elevation of the camera and the reduced resolution of the video image, the exact location of the apparent horizon is difficult. A small, 1 to 6 pixel measurement error can result in significant errors when computing distances from the film. However, correlation between calculated and measured distances can be high if surveying data is used to verify variables in the photogrammetric equations.

Positions on the ice in front of each camera were surveyed and marked with brightly colored flags in June, after all cameras were operating (Photograph 3). Figure 3 shows the position of the surveyed points relative to the CIDS and the cameras. Although the sea ice left, carrying the flags with it, or the flags on the barrier melted out, video analysis allowed us to mark and record the original pixel location of each flag. Knowing the measured distance from the cameras to the flags and their X,Y pixel coordinates on the video image provided us with the information necessary to establish the scaling factors for each camera.

SPRAY ICE BARRIER AND ICE CONDITIONS

General Description

The spray ice barrier was constructed in late 1984. The CIDS was located at a position defined by the geographical coordinates N 71° 02', W 152° 43'. This location is off the north coast of Alaska to the west of Harrison Bay, approximately nine miles offshore.

On Jan. 25, 1985 the six timelapse cameras were installed on the spray ice barrier. At the time of the camera installation the sea ice around the spray ice barrier had stabilized.

Photograph 2 is an aerial photograph of the CIDS and the spray ice barrier. In this photograph the spray ice barrier is defined by the smooth snow adjacent to the CIDS. The rougher buildup of ice lying outside the barrier is a rubble pile that formed on the northwest side of the barrier. The horseshoe shape of the barrier can also be observed. To provide the scaling for this photograph, the length across diagonal corners of the CIDS is approximately 400 feet.

Photograph 4, taken looking north into the open end of the spray ice barrier, provides a view of the CIDS and the spray ice barrier taken from level ice to the south. This photograph is similar to the above-ice portion of the cross-section of the barrier shown in Figure 2. To provide scale for this photograph, the main deck of the CIDS is approximately 50 feet above the level sea ice and the height of the top of the living quarters structure is 106 feet above the level sea ice. The width of the structure viewed in this photograph is 400 feet (across diagonal corners).

Referring to Table I and considering the camera elevations we can obtain an idea of the height of the barrier. Cameras 1, 2, 5 and 6 were placed on local high points around the CIDS.

Photograph 3. Picture taken from Camera 5', of the survey flags placed on the spray ice barrier for verifying photogrammetric measurements.

Photograph 4. View from sea level of CIDS and the spray ice barrier. This photograph was taken looking north. Note the helideck is approximately 100 feet above sea level.

Typical heights at the crest of the barrier were from 50 to 75 feet above sea level (Jahns & Petrie, 1986). Photograph 5 is taken from the top of the spray ice barrier looking toward the CIDS. As the photograph demonstrates, the height at which the photo was taken is nearly level with the main deck, which is at a height of approximately 50 feet above sea level.

Barrier and Sea Ice Conditions Prior to January 25, 1985

At the time the cameras were installed on the spray ice barrier on January 28, 1985 there was evidence of sea ice having moved against the barrier. Photograph 2 shows evidence of ice rubble piles where they formed against the spray ice barrier. The largest rubble pile was formed on the northwest side of the spray ice barrier. Smaller ice pileups occurred on the east and northeast side of the ice barrier.

We cannot tell the time at which the ice movements occurred. However, considering the size of the blocks making up the rubble piles we estimate that the more major of the two ice movements took place in either late December or early- to mid-January.

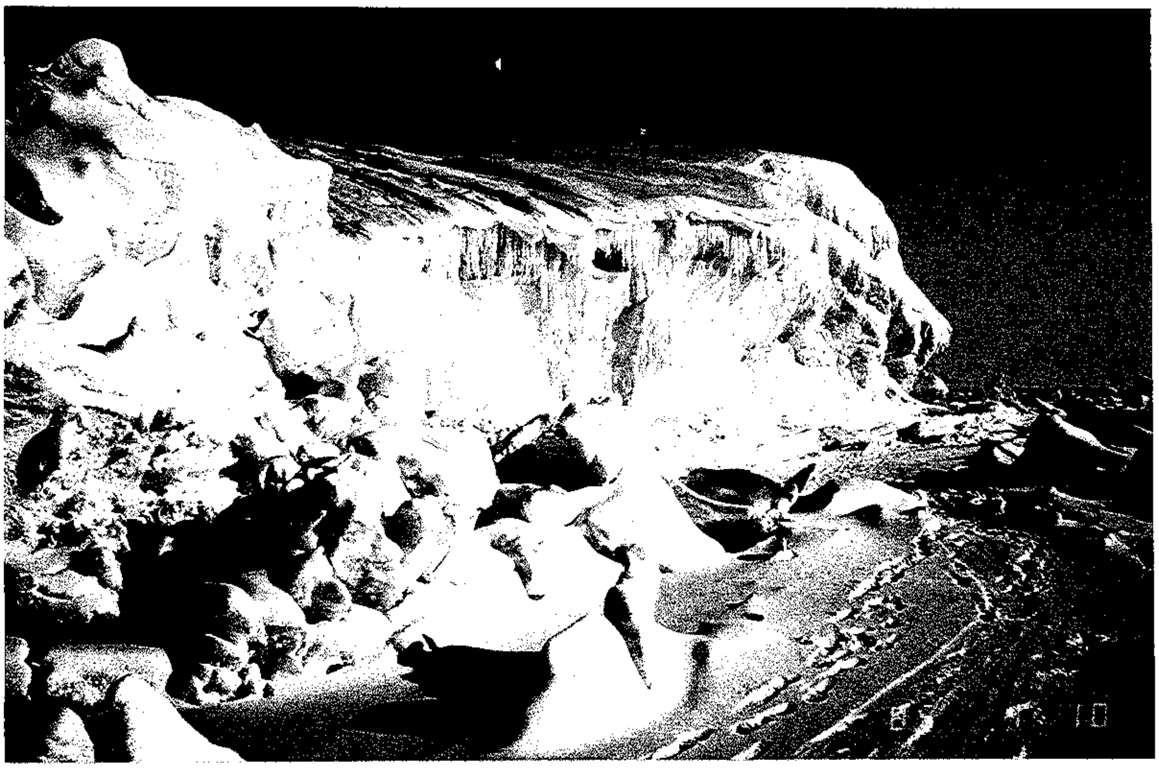
An ice movement from the northwest created a large rubble pile approximately 20 feet high on the northwest side of the spray barrier. Camera 4 was located on top of this rubble at a height of 23 feet. In general the spray ice barrier was very effective at stopping the ice from encroaching on CIDS.

The area of the barrier that was not effective in stopping the ice movement was the spray ice at the southwest end of the barrier. This was the area where the open end of the barrier terminated to allow access to the CIDS at sea level and also to allow an opening through which the CIDS could be moved out.

Photograph 6 shows the southwest end of the barrier where a portion of it was sheared off. The camera visible on top of the barrier is 55 feet above sea level. The higher ice at the left of the photograph is the start of the ice rubble pile.

We do not have access to the subsurface profiles of the spray ice barrier so it is difficult to be precise in trying to define why the barrier failed. Spray ice is relatively low density (between 600 and 850 kilograms per cubic meter) and the sintering between the ice grains is generally low. Considering this we would expect that the tensile and shear strength of the material would be low.

Photograph 5. Photograph of CIDS from the spray ice barrier looking toward the southwest. Note the height of the barrier relative to the elevation of the deck which is approximately 50 feet above sea level.



Photograph 6. A view at sea level of the sheared-off section of the barrier and part of the ice rubble pile on the northwest side.

We hypothesize that the area of the barrier that failed was not grounded. When the ice movement started the spray ice fractured and the south portion was carried away with the continuing ice movement. Most likely the barrier fractured at a point beyond where it was grounded.

Except for the end of the barrier that was carried away, it was effective in creating a pile-up of sea ice.

Sea ice also impacted and piled up against the barrier on the east side. Photograph 7 shows the low relief pileup that occurred on the eastern side of the CIDS. The extent of the pileup on the eastern side was not as extensive as that on the western side of the CIDS. There appeared to be no breakup of the barrier on this side.

Barrier and Sea Ice Conditions January through June 8, 1985

The purpose of the winter deployment of the cameras was to observe the effects of ice movements against the spray ice barrier. Five cameras were placed at locations on the spray ice barrier. One camera was placed on the rubble pile on the west side of CIDS. From January to June during the course of this phase of the monitoring program generally there were no detectable ice movements. There may have been low amplitude ice movements below what we could resolve photographically. Typically movements of ice of a meter or less are difficult to detect with the equipment in use.

After the period of very active ice movement in December or January the ice around the CIDS stabilized. Even though the CIDS was located nine miles offshore in 55 feet of water the ice became shorefast and remained that way for the entire winter.

At the end of May and into June changes started to take place in the ice surrounding the spray barrier. These changes consisted of the formation of melt ponds on the sea ice surface. Some change in the texture of the spray ice itself was also observed. In the videotape that accompanies this report a number of video scenes of the spray ice barrier as it appeared throughout the winter season are presented. These film cuts are shown to demonstrate the static nature of the sea ice during the winter period and also to show that little or no detectable changes took place in the spray ice barrier.

Photograph 7. A view of the low-relief rubble that formed on the east side of the barrier. The build up on the east was not as extensive as that on the northwest.

Barrier and Sea Ice Conditions June 9 through August 17, 1985

During the summer monitoring period a great deal of activity took place in the ice around CIDS. The breakup of the sea ice occurred, the spray ice barrier underwent significant melting, and calving of large blocks from the barrier took place. By the time the CIDS was moved on August 17, 1985 only a remnant of the barrier remained.

In Appendix A we have provided a catalogue of events that took place during the summer period. In general there were few changes noted in the barrier prior to the breakup of the natural ice sheet. Once breakup did occur, the breakup of the spray ice barrier was quite rapid due to wave action undercutting the barrier.

The dissolution of the spray ice barrier during the open water season took place in a progressive manner, i.e., the barrier did not simply float away in one massive ice movement, but failed in smaller increments.

The sequence of barrier failure was that first, a portion of the barrier would be undercut at the waterline until the overhanging block above failed. The material would fracture and, if the sea was at all rough, it would be carried away by ocean currents. If the sea were calm, the material would remain resting on the submerged section of the barrier. However, when the overburden was removed from a submerged section of the barrier, this section would become unstable and float to the surface.

As indicated, we have provided a detailed log of ice events keyed to the film frame numbers in Appendix A. In Appendix A we have provided data on ice cover, the sky condition, sea state, and observed events that took place around the spray ice barrier on a nearly day-by-day basis. In this section we summarize the sequence of events that took place during the summer of 1985 until the CIDS was moved on Aug. 17, 1985.

From the time the cameras were moved to the CIDS on June 9 until the end of June 27 no ice movement was recorded. During this period the ice concentration around the CIDS was total (ice concentration 10/10). As June progressed, more and more melt ponds became evident. During this time the winds were generally calm and the cloud cover ranged from high overcast to clear.

On June 27 the first ice movement (in view of the cameras) was noted. During the period from June 27 through June 29 intermittent ice movement was recorded by camera 1' to the north of the spray ice barrier. Camera 2' (azimuth 078°) recorded an ice movement on June 27 and Camera 4' (azimuth 045°) recorded an ice movement to the north; on June 29 this camera recorded an ice movement to the east. The ice movements recorded during this period were generally low amplitude movements with the ice shifting only on the order of 10 meters at any given time. When this series of ice movements stopped the ice coverage in the area was still total (IC=10).

The first significant breakout of the sea ice took place on July 3 when the ice moved away from the spray ice barrier to the northeast. This left an area of open water between the barrier and the ice edge. On July 4 the ice moved against the barrier on the east side. This movement produced some ridge formation in view of the cameras. This intermittent ice movement continued until July 7 with the outer edge of the barrier in the eastern sector standing in open water at the end of the period.

During the period of ice movement in the later part of June and the beginning of July we did not find any correlation between ice movement and winds. Visual indicators that could be observed in the films showed that the winds were generally calm or low speed. At the end of filming for this period, which took place on July 9, we estimated the overall ice coverage as 9/10 (IC=9).

During the period from June 9 to July 9 we noted some changes in the spray ice barrier around the CIDS. One of the most notable changes was the apparent lowering of the spray ice barrier due to melting, settlement and sublimation. This ablation of the barrier was particularly noticeable on the film record from Camera 4' on the southeast side of the CIDS and Camera 5' which was at deck level looking at the inner rim of the barrier.

From the film record we estimate that the barrier decreased in height some 11 feet between June 26 until July 31. This calculates to an average loss of vertical height of 0.31 feet per day. During the winter period with the cameras on the barrier itself we were not in position to note settlement of the barrier. When the cameras were moved onto the CIDS we noted some loss of vertical height in June and a somewhat greater loss of height in July.

The first major change took place at the southeast section of the barrier on June 25 when a large block of ice rotated and moved. This was followed by some fracturing of the ice around the barrier on the following day.

Camera 5' was located at deck level to monitor the inner section of the spray ice barrier. The view from Camera 5', which looks to the east-southeast (115°), is presented in Photograph 3. The data recorded from Camera 5' shows how the interior side of the barrier was affected by the relatively calm waters in the moat between the barrier and the CIDS.

During the June deployment no major (naturally occurring) changes were recorded by Camera 5'. However, we did note several small changes in the barrier, the most significant being the undercutting of the spray ice barrier at water level. Through the month we were able to detect undercutting of the barrier even though the water on the inside was relatively calm. We found that the undercutting of the barrier and the subsequent calving of the cantilevered section were the most important factors in the mass wasting process.

The second noticeable effect was the lowering of the barrier height due to melting, sublimation and settling. This was particularly evident on the small hillock that can be observed in Photograph 3.

In general during the first summer monitoring period from June 9 through July 11 we did not observe any naturally occuring major degradation of the spray ice barrier. We did observe the general breakup of the natural sea ice. This was accompanied by a period of open water around the barrier alternated with periods when the ice cover was nearly total. At the end of the June-July period the ice cover at the barrier was about 9/10. At this time the barrier had the strength to withstand ice impacts as evidenced by the rubble development that was observed near it. The most destructive event that we observed during this interval was the undercutting of the barrier by water, one of the mechanisms for breaking down the structure.

The cameras were serviced on July 9 and 10 and put back into operation. The major change in camera deployment for this period was the demobilization of Camera 5' and the installation of Camera 6'. Camera 3' was installed above the crew quarters at an elevation of 106 feet above sea level.

This camera was directed to monitor activity around the barrier toward the west. During this period of monitoring which lasted until Aug. 17 much of the barrier around the southeast and southwest sides of the CIDS was washed away.

Camera 1' presented a view of the barrier from an elevation of 119'. This camera was mounted on top of the elevator shaft and looked north over the main deck toward the inside of the barrier north of CIDS. The film from this camera provided a good view of the inner edge of the barrier to the north and an excellent view of ice conditions beyond the barrier. At the end of the monitoring period at the Antares Prospect on Aug. 17, 1985 this camera was the only unit that showed a substantial amount of the barrier still intact.

From July 9 through July 13 the ice cover to the north of the CIDS was nearly total, with ice concentrations ranging from 9/10 to 10/10. During this period little ice movement was recorded. On July 13, a period of ice movement began which continued throughout the monitoring period. The ice concentration, which was 9/10 on July 13, decreased constantly through the remainder of the monitoring program. By July 24 the ice concentrations were down to 2/10 and remained at 2/10 or less until Aug. 17 when the CIDS was moved.

The primary change that we noted from the film from Camera 1' was a general lowering of the barrier from melting, sublimation and settlement during July and August. Since erosion caused by calving of the barrier took place mainly on the seaward side, we could not view this from the Camera 1' records. On Aug. 10 we did observe a calving event that took place on the protected inner edge of the barrier.

Camera 1' also provided one of the last views of the barrier that we monitored as the CIDS was being towed from the Antares Prospect to the Orion drill site. As can be observed in the videotape accompanying this report, at the time the CIDS was moved the spray ice barrier had lost a significant amount of its original mass.

While Camera 1' provided a generally global view of the barrier during July and August, the other cameras were focused on indivdual sections of the barrier. Specifically the remaining five cameras were directed to record the activity at the southwestern and southeastern flanks of the barrier. The general form of the horseshoe-shaped barrier with the open end toward the south can be seen in Photograph 2 which is an areal view looking east. A view into the open end of the barrier can be seen in Photograph 4 looking to the north. It was the open ends of the barrier that were the most susceptible to erosion. From the vantage point of the cameras the erosion of the barrier seemed to progress from each of the two open ends.

Cameras 2', 4' and 6' were set up to view the southeastern side of the barrier, and Camera 3' was set to view the southwestern end of the barrier. From July 9 through the end of July no major calving events took place. On Aug. 4, Camera 2' recorded the first major breakup of the barrier at the southeastern end. Over the next two days approximately 200 feet of barrier were progressively washed away. On Aug. 6, the southeast segment of the barrier was no longer in view of Camera 2'. We did not detect any major storm activity during the two-day period in which the barrier progressively disintegrated.

The sea state (as defined in association with the Beaufort wind scale (3)) varied from 0 to 3, during this period. A sea state 0 is described as a sea that may range from calm to one where "ripples with the appearance of scales are formed but without foam crests." A sea state 3 is described as having "small waves becoming longer, fairly frequent white caps." It was evident that the accelerated rate of barrier disintegration was associated with the increased undercutting of the berm by heightened wave activity.

Camera 3', which was set to record ice and barrier activity on the southwest side of the CIDS, recorded a pattern of disintegration very similar to what was viewed on the southeastern flank. On Aug. 5, the film was changed in all the cameras and they continued to record ice activity. By Aug. 7, the barrier that had been in view on both the southeast and southwest sides of the CIDS had receded from the cameras' field of view.

From Aug. 7, until the CIDS was moved on Aug.17, the only camera with a view of the spray ice barrier was Camera 1'. Between Aug. 7 and Aug. 17 the rate of disintegration of the barrier appeared to decrease significantly. This is witnessed by the fact that a significant section of the barrier was intact when the CIDS was moved.

The events described in this section are documented visually in the accompanying videotape.

WATER JET EXPERIMENT

In compiling the film logs for the the spring and early summer period (see Appendix A) a number of references are made to the appearance of water jets. Examples of these water jets are shown in the videotape that accompanies this report. Although we did not have access to information on the nature or intent of these experiments, it would appear that an attempt was being made to either melt or cut the barrier using water trained on the barrier. We hypothesize that the water was directed at the barrier from the same water cannons that were used to build it.

Examination of the film record indicates that the technique as it was employed was not highly effective as a means of removing the barrier. As a method of melting the barrier it appeared that not enough energy transfer took place between the water from the water cannons and the spray ice material. However, in one sequence we observed a calving of a section of barrier that was undercut by wave action. The stream of water directed at the barrier appeared to overload the section of barrier and it calved off.

CONCLUSIONS

Currently there is an interest in using spray ice technology to solve a number of problems in the offshore Arctic. The spray ice barrier constructed around the CIDS was probably the first application of this technology in the American Beaufort Sea. In 1986 AMOCO and its partners, after several years of experimentation, constructed a spray ice island off of Cape Halkett, not far from the site of EXXON's spray ice barrier.

With the construction of the spray ice barrier EXXON demonstrated that it was feasible to construct a protective barrier around an offshore structure. AMOCO, with its Mars Island construction, demonstrated that a successful oil drilling operation can be carried out from spray ice.

Construction costs with spray ice are generally less than the costs associated with gravel. Given this fact it would appear that spray ice will see wider use in the future. The two primary questions arising from construction with spray ice concern the maximum water depth at which a spray ice structure can be constructed and how late into the summer season operations can take place on them. To some extent the answers to these questions depend on the what the spray ice structure is designed and built for.

In the case of the spray ice barrier around the CIDS, the water depth was on the order of 50 feet. The structure was constructed in November and December of 1984, and it served as an adequate barrier protecting the CIDS from ice until the end of July of 1985. At that time water eroding away the base of the structure caused a rapid collapse of the barrier by calving of the ice into the ocean. Thus in terms of a protective barrier there appears to be little problem for operating at 50-foot water depths well into the summer season in areas where the ice is landfast.

In terms of operating a spray ice structure as a drilling platform it is likely that the guidelines for operation would be somewhat more conservative. Given the ice and weather conditions of the winter of 1984 and 1985 it would appear that a drilling operation could be carried out from a spray ice island in 50-foot water depths with similar ice conditions.

This is assuming that other factors such as settlement and creep of the material (which this study did not address) were within acceptable limits. The primary difficulties in constructing a spray ice island would be the logistical problems of mobilizing and demobilizing equipment over thin ice in the early season. Demobilizing equipment over the weaker ice in the spring would also present a problem.

In terms of this specific investigation we found that:

1. The barrier as constructed gave adequate protection against ice movements during both the freeze-up and breakup periods.

2. We detected few changes in the spray ice barrier during the period from January, 1985 until June 1985. Little ice movement took place during this period.

3. In June the cameras were moved from the spray ice barrier to sites on the CIDS to monitor the sea ice and spray barrier. From that time until July 30 the prime factors affecting the barrier appeared to be melting, sublimation and settling.

4. With the decrease in the ice concentration around the barrier, undercutting of the barrier at water level began. The rate of undercutting increased with the amount of wave activity. When a section of the barrier was undermined the overhanging section would then calve off. With this type of failure mechanism the rate of retreat of the barrier was as high as 100 feet per day at its ends.

5. A large section of the barrier lasted into mid-August. It would appear that with proper slope protection a large spray ice structure could last through the open water season.

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APPENDIX A

SUMMARY OF FILM DATA; JUNE THROUGH AUGUST 1985

LIST OF ABBREVIATIONS

AZ	AZIMUTH
E	EAST
IC	ICE CONCENTRATION
IF	ICE FREE
IM	ICE MOVEMENT
LRG	LARGE
N	NORTH
NE	NORTHEAST
NW	NORTHWEST
S	SOUTH
SE	SOUTHEAST
SW	SOUTHWEST
SUBM	SUBMERGED
T	TRACE
W	WEST

CAMERA 1' AZIMUTH 360° ELEVATION 119' JUNE 1985

FRAME NUMBER	DATE JUNE	TIME (AST)	COMMENTS
02001117	9	1722	PREBREAKUP VIEW TO THE N
02002000	10	1958	IC=10 VIEW FROM ABOVE HELIDECK
02002800	11	2116	IC=10 A FEW MELT PONDS VISIBLE
02003600	12	2234	GENERALLY NO CHANGE
02004400	13	2352	NO CHANGE; SKY OVERCAST
02005200	15	0111	IC=10 NO CHANGE: MELT PONDS
02010000	16	0229	NO CHANGE
02010800	17	0347	NO CHANGE IC=10
02011600	18	0505	NO CHANGE; MORE MELT PONDS
02012400	19	0623	MOAT VISIBLE AROUND BARRIER
02013200	20	0741	NO CHANGE
02014000	21	0859	NO CHANGE; IC=10
02014800	22	1017	NO CHANGE; IC=10
02015600	23	1135	NO CHANGE; IC=10
02020400	24	1254	NO CHANGE; IC=10
02021200	25	1412	NO CHANGE; IC=10
02022000	26	1530	NO CHANGE; IC=10
02022800	27	1648	NO CHANGE; IC=10
02023120	28	0428	IM TO THE W
02023600	28	1806	MOVEMENT STOPS; IC=10
02022502	27	0732	IM TO THE NE
02023121	28	0435	IM TO THE W; SMALL AMPLITUDE
02024400	29	1924	ICE STOPS MOVING
02025200	30	2042	NO MOVEMENT; IC=10

CAMERA 1' AZIMUTH 360° ELEVATION 119' JULY 1985

FRAME NUMER	DATE	TIME (AST)	COMMENTS
02030000	1	2200	IC=10; NO MOVEMENT
02030914	3	0400	ICE STARTING TO MOVE NE
02031126	3	1138	MAJOR BREAKOUT OF ICE TO THE NE
02032026	4	1606	ICE MOVE AGAINST BARRIER
02032804	5	1500	CONTINUED IM
02032804	5	1500	RIDGES FORMING ; IC=10
02033600	6	1552	CONTINUED MOVEMENT AND RIDGING
02034501	7	2026	MOVEMENT CHANGES TO THE W
02035400	9	0047	MOVEMENT STOPPED: IC=10
02035927	9	1933	END OF FILM REEL
02042824	9	2040	NEW FILM REEL INSTALLED
02043000	10	0023	NO MOVEMENT; IC=10
02043800	11	0145	ABLATION OF BARRIER
02044320	11	1947	FOG AND LOW VISIBILITY
02044820	12	1138	ICE ON CAMERA CASE CLEARS
02045427	13	0725	IM TO THE S
02045505	13	0811	ICE SHEARS N OF BARRIER
02045620	13	1259	ICE STOPS MOVING; IC=9+
02050400	14	1209	NO MOVEMENT THIS PERIOD
02050626	14	1220	FOG & ICE ON LENS
02051129	15	1331	FOG AND ICE CLEARS
02051401	15	1958	ICE MOVES TO THE S
02051617	16	0403	IM STOPS
02052400	17	0333	CONTINUOUS IM
02053707	18	2131	ICESHEET BREAKING UP
02054815	20	0916	IM TO THE SW; IC DOWN
02055622	21	1123	ICE BREAKING INTO FLOES
02060400	22	1020	NO MOVEMENT; IC=7
02060200	23	1141	NO MOVEMENT; MEDIUM FLOES;IC=7
02062000	24	1303	ICE MOVES TO THE W
02062800	25	1424	IC DROPS TO 2-3
02063500	26	1235	LOW CON IM
02064400	27	1707	LOW CON IM CONTINUES
02065202	28	1842	IC=2
02070000	29	1950	IC=3; BARRIER ABLATING
02070800	30	2111	IC=2; NO CHANGE
02071600	31	2233	IM; DIRECTION VARIABLE

CAMERA 1' AZIMUTH 360° ELEVATION 119' AUGUST 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
02072400	1	2354	NO ICE NEARBY; SEA CALM
02073129	3	0115	IC=1; SEA CALM
02073526	3	1337	FOG
02074116	4	0732	FOG AND ICE ON LENS CLEARS
02074925	5	0952	END OF FILM REEL
03001001	5	1500	NEW FILM REEL INSTALLED
03001800	6	1625	IC=0; BARRIER STILL IN PLACE
03002600	7	1757	IC=2; IM PAST BARRIER
03003400	8	1929	IC=1; IM TO THE W
03004027	9	1736	CIDS RAISED AND LOWERED
03004919	10	2127	LRG SECTION OF BARRIER CALVES
03005800	12	0005	BARRIER STILL IN PLACE
03010406	12	1954	FOG IN THE AREA
03011225	13	2331	IC=2; MANY SMALL FLOES
03012000	14	2218	FOG IN AREA; LITTLE CHANGE
03012714	15	2211	FLOES MOVING E
03013022	16	0839	LRG SECTION OF BARRIER CALVES
03013725	17	1719	TOW OF CIDS BEGINS
03013727	17	0732	DISTANT VIEW OF BARRIER
03013729	17	0745	LAST FRAME WITH BARRIER

CAMERA 2' AZIMUTH 078° ELEVATION 106' JUNE 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
10002225	9	1737	PREBREAKUP VIEW TO THE NE
10002916	10	1203	MARKER FLAG #1 SET; IC=10
10002919	10	1220	MARKER FLAG #2 SET
10025317	27	0100	IM TO THE NW; IC=10
10025715	27	1150	END OF LOW AMPLITUDE IM

CAMERA 2' AZIMUTH 078° ELEVATION 106' JULY 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
10034526	3	0110	IM TO THE E
10041716	6	1624	END OF IM
10043110	8	0625	END OF FILM REEL
10043924	9	1842	NEW FILM REEL INSTALLED
10051422	13	1458	IM TO S; RUBBLE PILE MOVES
10051424	13	1509	IC=9
10051726	13	2315	IM STOPS; IC=9+
10052922	15	0635	NO MOVEMENT
10053926	16	0922	IM TO THE S
10055307	17	2037	IM STOPS; IC=10
10060310	18	2318	IM TO THE SE; IC=9+
10070916	26	0611	CONTINUOUS IM; ICE BREAKS UP
10070917	26	0617	OPEN WATER AT BARRIER EDGE
10071919	27	0852	FLOES MOVING IN THE AREA
10072624	28	0349	FLOE SIZE DECREASING; IC=5
10074305	29	2300	FLOES MOVING; IC=5

CAMERA 2' AZIMUTH 078° ELEVATION 106' AUGUST 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
10080514	1	0955	OPEN WATER
10080515	1	1001	SEA CALM; BARRIER MELTING
10081024	2	0003	RUBBLE PILE DISINTEGRATING
10081716	2	1748	BARRIER BEING UNDERCUT; IC=1
10081717	2	1754	SEA CALM; FLOES VISIBLE
10083422	4	1515	FLOES MOVE AGAINST BARRIER
10083309	4	1126	BARRIER BEGINS TO BREAK DOWN
10083907	5	0306	BARRIER BREAKS DOWN FROM E&S
10083921	5	0422	BLOCKS FALL; REST ON SUBM ICE
10083927	5	0455	MORE CALVING; BLOCKS IN PLACE
10083929	5	0506	BLOCKS FLOAT AWAY; IC=0
10084000	5	0506	SEA CHOPPY; BLOCKS CALVING
10084201	5	1029	CALVING AT S END OF BARRIER
10084219	5	1207	ICE FLOATS TO SURFACE
10084220	5	1212	ICE BLOCKS WASH AWAY
10084300	5	1302	ICE WELLING UP; BLOCKS CALVING
10084329	5	1540	CAMERA SLATED OFF
10084400	5	1540	FILMED IN REAL TIME
10200810	5	1555	NEW FILM REEL INSTALLED
10200822	5	1704	BLOCKS BREAK OFF S END
10200824	5	1716	SEA SHOWS LIGHT CHOP
10200922	5	1951	BLOCKS BREAK OFF S END
10201011	5	2134	BLOCKS BREAK OF SE SIDE; IC=0
10201012	5	2140	UNDERCUTTING OF BARRIER
10201017	5	2209	BLOCK CALVES OFF S SIDE
10201119	6	0107	CALVED BLOCKS ON SUBM ICE
10201209	6	0256	RUBBLE FLOATS TOWARD BARRIER
10201210	6	0301	RUBBLE GROUNDS OFF BARRIER
10201219	6	0353	SUBMERGED ICE COMES TO SURFACE
10201225	6	0428	SMALL BLOCKS BREAK OFF
10201401	6	0743	SMALL BLOCKS BREAK OFF
10201425	6	1001	ICE BREAKS OFF E SIDE
10201507	6	1104	NO BARRIER IN FRAME
10201508	6	1109	OPEN WATER SMALL SWELLS;IC=0
10202701	7	1947	LOW CONCENTRATION INVASION

CAMERA 3' AZIMUTH 265° ELEVATION 106' JULY 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
06113705	10	1825	CAMERA INSTALLED
06114411	11	0339	IC=9+; BARRIER CALVING
06114624	11	0647	WATER JET ON
06115620	11	1926	WATER JET OFF
06120627	12	0834	WATER JET ON
06120920	12	1206	IM TO THE E
06121627	12	2124	WATER JET OFF
06122124	13	0340	IM TO THE E
06122629	13	1018	WATER JET ON
06123701	13	2310	WATER JET ON
06124729	14	1314	WATER JET ON
06131219	15	2051	WATER JET OFF; FOG IN AREA
06132021	16	0712	EFFECTS OF WATER JET VISIBLE
06133220	16	2233	IM AGAINST BARRIER
06134021	17	0851	IC=10
06140119	18	1141	IC=8; SEA CALM; BROKEN ICE
06142021	19	1209	IM AGAINST BARRIER
06144020	20	1345	CONDITIONS UNCHANGED
06145104	21	0309	IC=9+; IM AGAINST BARRIER
06150014	21	1508	IM AWAY FROM BARRIER
06152021	22	1705	LITLE CHANGE; IF NEAR BARRIER
06154024	23	1852	LITTLE CHANGE
06160000	24	1927	IC=7
06162017	25	2151	IC=7; LITTLE CHANGE
06164019	26	2335	IM AROUND BARRIER
06170012	28	0055	CONDITIONS UNCHANGED
06172021	29	0258	IC=7
06174019	30	0432	NUMEROUS ICE FLOES IN AREA
06180026	31	0629	IC=2; SMALL FLOE SIZE

CAMERA 3' AZIMUTH 265° ELEVATION 106' AUGUST 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
06182014	1	0736	IC=2; SMALL FLOES IN AREA
06184002	2	0843	BARRIER MELTING
06190009	3	1041	SEA CALM
06190309	3	1431	ICE CALVING FROM BARRIER
06191702	4	0810	BLOCK CALVES AND REST ON SUBM ICE
06192126	4	1421	MORE CALVING FROM BARRIER
06192410	4	1730	BLOCK CALVES FROM END OF BARRIER
06192724	4	2158	BLOCKS RESTING ON SUBMERGED ICE
06194411	5	1911	CONTINUED BARRIER DEGRADATION
06194415	5	1922	END OF FILM REEL
07002800	5	2028	NEW FILM REEL INSTALLED
07002801	5	2030	VIEW OF BARRIER LOOKING SW
07002802	5	2032	IC=T; SMALL SECTION OF BARRIER LEFT
07002910	5	2204	LARGE BLOCK BREAKS OFF
07002911	5	2206	BLOCK RESTS ON SUBMERGED BARRIER
07003622	6	0654	LARGE SECTION OF BARRIER BREAKS AWAY
07003622	6	0654	MUCH BARRIER DEBRIS IN THE WATER
07003912	6	1004	SMALL BLOCK BREAKS OFF
07005404	7	0337	END OF BARRIER BREAKS OFF
07041821	17	0731	CIDS MOVED FROM LOCATION
07041822	17	0734	PORTION OF THE BARRIER IS INTACT

CAMERA 4' AZIMUTH 108° ELEVATION 60' JUNE 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
00000605	9	1845	IC=10; PREBREAKUP CONDITION
00001126	10	1138	MARKER FLAGS SET OUT FOR C2'
00001202	10	1209	MARKER FLAG SET OUT FOR C2'
00001402	10	1803	MARKER FLAG SET FOR C6'
00002400	11	2322	IC=10; MELT PONDS; CRACKS IN BARRIER
00003200	12	2259	NO CHANGE; SKY CLEAR
00004000	13	2237	NO CHANGE; SKY CLEAR
00004800	14	2214	NO CHANGE; SKY CLEAR
00005400	15	1556	NO CHANGE; MOVEMENT IN MELT PONDS
00010000	16	0939	IC=10
00010800	17	0916	IC=10; NO IM
00011600	18	0853	FREEZING OF MELT PONDS
00012400	19	0830	IC=10; NO NOTICEABLE CHANGE
00013200	20	0807	IC=10; SURFACE MELTING VISIBLE
00014000	21	0745	IC=10
00014800	22	0722	FLAGS APPEAR TO CREEP
00015600	23	0659	IC=10
00020400	24	0636	IC=10; NO IM
00021019	25	0215	LARGE BLOCK SHIFTS AND ROTATES
00021200	25	0613	IC=10; ICE NOT MOVING
00022400	26	1738	ABLATION NOTICEABLE
00022907	27	0907	ICE MOVES TO THE N
00023200	27	1716	ICE MOVEMENT ENDS
00024000	28	1653	NO MOVEMENT THIS PERIOD
00024800	29	1630	IC=10; INCREASED MELTING
00024902	29	1939	LOW AMPLITUDE IM TO THE E
0025600	30	1607	IC=10; NO MOVEMENT

CAMERA 4' AZIMUTH 108° ELEVATION 60' JULY 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
00030400	1	1544	SEA ICE DEGENERATING
00031200	2	1521	MUCH SURFACE MELT
00031206	2	1558	WATER JET ON
00031726	3	0845	SHIFT OF ICE BLOCKS
00032012	3	1611	IM STARTING
00032824	4	1702	ICE MOVING AWAY FROM BARRIER
00032000	3	1458	WATER JET ON
00033001	4	2035	WATER JET ON
00033316	5	0658	OPEN WATER AROUND BARRIER
00033802	5	2019	WATER JET ON
00034600	6	1943	OPEN WATER AROUND BARRIER
00035400	7	1921	CONDITIONS UNCHANGED
00040200	8	1858	SEA CALM; CONDITIONS UNCHANGED
00041000	9	1835	SEA CALM
00041420	10	0825	END OF FILM REEL
00043601	10	0927	NEW FILM REEL INSTALLED
00043905	10	1836	WATER JET ON
00044400	11	0842	SEA CALM; ICE STANDING OFF
00045200	12	0803	LIGHT CHOP TO THE SEA
00050000	13	0724	SEA CALM; ICE STANDING OFF
00050011	13	0830	IM TO THE S
00050120	13	1220	RUBBLE PILE MOVES
00050120	13	1220	IM STOPS
00050800	14	0645	ICE STABLE; NO CHANGE
00051600	15	0606	FOG IN AREA
00052116	15	2219	IM TO THE S
00052224	16	0202	RUBBLE PILE GROUNDS
00052606	16	1154	IM TO THE S CONTINUES
00053200	17	0449	IM STOPS; IC=8+
00054000	18	0410	INTERMITTENT IM
00054800	19	0331	INTERMITTENT IM
00055221	19	1719	GROUNDED RUBBLE PILE MOVES OFF
00060000	20	1433	FRAGMENTED ICE IN AREA
00060800	21	1354	IM AGAINST BARRIER
00061600	22	1315	IC=8+
00062400	23	1236	CONTINUOUS ICE MOVEMENT
00063101	24	0908	IC=8+;RUBBLE PILE MOVES
00063200	24	1158	IC=8+; RUBBLE PILE GROUNDED
00064000	25	1119	NO CHANGE IN BARRIER; SEA CALM
00064800	26	1040	SEA CALM; IC=3
00065600	27	1001	SEA CALM; NO CHANGE IN BARRIER
00070400	28	0922	SEA CALM; IC=3
00071200	29	0844	SOME BARRIER MELTING
00072000	30	0805	LRG FLOES MOVING INTO AREA
00072800	31	0726	LITTLE CHANGE, BARRIER INTACT
00073206	31	1943	SECTION OF BARRIER CALVES OFF

CAMERA 4' AZIMUTH 108° ELEVATION 60' AUGUST 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
00073614	1	0812	BROKEN BLOCKS MOVE OFF
00074324	2	0538	BLOCKS CALVE AND REST ON SUBM BERM
00074811	2	1855	BLOCKS CALVE FROM BARRIER
00075114	3	0359	BARRIER BREAKS AWAY
00080200	4	1041	IC=4;SEA CALM; ICE MOVING
00080502	4	1938	LRG BLOCK CALVES OFF
00080617	5	0004	BARRIER FRAGMENTS LIGHTLY GROUNDED
00080627	5	0105	LAST OF BARRIER IN FIELD OF VIEW DISAPPEARS
00080715	5	0247	BARRIER DEBRIS IN THE WATER
00081106	5	1333	END OF FILM REEL
01000910	5	1352	NEW FILM REEL INSTALLED
01001022	5	1424	FRAGMENTS OF BARRIER FLOATING BY
01001804	5	1709	LARGE BLOCK CALVES OFF
01001819	5	1720	FRAGMENT RESTING ON SUBMERGED ICE
01002422	5	1936	LARGE BLOCK BREAKS OFF
01002922	5	2128	SMALLER BLOCK BREAKS OFF
01003120	5	2211	BLOCK BREAKS OFF; SEA STATE 3
01003806	6	0036	MORE BLOCKS CALVE OFF
01003902	6	0056	LARGE BLOCK CALVES OFF
01004421	6	0302	RUBBLE GROUNDS OFF BARRIER
01005124	6	0540	SMALL BLOCK BREAKS AWAY
01005422	6	0646	END OF SEQUENCE; BARRIER HAS RETREATED OUT OF THE FIELD OF VIEW

CAMERA 5' AZIMUTH 108° ELEVATION 47' JUNE 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
06005521	10	1455	PREBREAKUP ICE CONDITION
06011000	10	0548	VIEW INSIDE BARRIER FROM DECK OF CIDS
06012527	12	0348	NO APPARENT CHANGE IN BARRIER
06015419	13	1453	LITTLE CHANGE IN BARRIER
06020602	14	0449	SOME MELTING APPARENT
06022024	14	2251	LITTLE CHANGE IN BARRIER
06024022	15	2311	LITTLE CHANGE VISIBLE
06030025	16	2344	MOTE ENLARGING
06032020	17	2357	LITTLE CHANGE
06034019	19	0020	LITTLE CHANGE IN BARRIER
06040100	20	0111	LITTLE CHANGE IN BARRIER
06042101	21	0139	LITTLE CHANGE IN BARRIER
06044019	22	0136	MELTING AT SEA LEVEL APPARENT
06050017	23	0157	LITTLE CHANGE IN BARRIER
06052000	24	0140	LITTLE CHANGE IN BARRIER
06054025	25	0308	LITTLE CHANGE IN BARRIER
06060016	26	0311	MELTING AT SEA LEVEL EVIDENT
06062021	27	0349	LITTLE CHANGE IN BARRIER
06064015	28	0359	LITTLE CHANGE IN BARRIER
06070101	29	0503	MELTING AT SEA LEVEL EVIDENT
06072029	30	0526	LITTLE CHANGE IN BARRIER

CAMERA 5' AZIMUTH 108° ELEVATION 47' JULY 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
06074022	1	0534	LITTLE CHANGE IN BARRIER
06080007	2	0521	MELTING AT WATER LEVEL EVIDENT
06081922	3	0511	LITTLE CHANGE IN BARRIER
06084021	4	0648	UNDERCUTTING OF BARRIER VISIBLE
06090024	5	0721	LITTLE CHANGE IN BARRIER
06090202	5	0852	WATER JET ON
06090312	5	1030	WATER JET OFF
06091622	6	0248	LRG BLOCK CALVES OFF
06092014	6	0721	ICE BLOCK MOVING IN FOREGROUND
06094014	7	0747	LITTLE CHANGE IN BARRIER
06100006	8	0752	LITTLE CHANGE IN BARRIER
06102025	9	0905	A GREAT DEAL OF MELTING SINCE START OF FILM
06104020	10	0918	LITTLE CHANGE IN BARRIER
06104100	10	0941	END OF FILM REEL; CAMERA MOVED TO NEW LOCATION

CAMERA 6' AZIMUTH 173° ELEVATION 20' JUNE 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
11001600	10	1549	PREBREAKUP VIEW
11001627	10	1838	MARKER FLAGS SET OUT
11002400	11	1553	DAY OVERCAST; BARRIER INTACT
11002800	12	0355	DAY OVERCAST; LITTLE CHANGE
11003300	12	1857	DAY OVERCAST; LITTLE CHANGE
11003700	13	0659	DAY OVERCAST; LITTLE CHANGE
11004500	14	0703	DAY OVERCAST; LITTLE CHANGE
11005300	15	0707	DAY OVERCAST; IC=10
11010100	16	0710	DAY OVERCAST; LITTLE CHANGE
11010900	17	0714	DAY OVERCAST; IC=10
11011700	18	0718	DAY OVERCAST; LITTLE CHANGE
11012500	19	0721	DAY OVERCAST; LITTLE CHANGE
11013400	20	1026	SKY CLEARING; IC=10
11014100	21	0729	SKY PARTIALLY OBSCURED; IC=10
11014900	22	0732	SKY CLEAR; IC=10
11020500	24	0740	SKY OVERCAST; IC=10
11021300	25	0744	ICE STARTING TO MOVE
11022100	26	0747	CRACKS FORMING AT S END OF BARRIER
11022725	27	0426	FIRST IM TO THE NW; IC=10
11023122	27	1609	END OF LOW AMPLITUDE IM

CAMERA 6' AZIMUTH 173° ELEVATION 20' JULY 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
11031525	3	0448	SECOND IM STARTS
11032811	4	1827	WATER JET ON
11033326	5	1102	WATER JET CONTINUES
11034120	6	1029	WATER JET OFF
11034900	7	0828	ICE STANDING OFF
11041226	10	0820	END OF FILM REEL
11043817	10	0810	NEW FILM REEL INSTALLED
11044016	10	1404	WATER JET ON
11044522	11	0542	S END BREAKS AWAY
11044605	11	0657	S END MOVES OUT
11044605	11	0657	ICE STANDING OFF; SEA CALM
11045200	12	0027	SEA CALM; NO IM
11050000	13	0029	SEA CALM; ICE NOT MOVING
11050800	14	0031	SEA CALM; IM STARTS
11051600	15	0033	SEA CALM
11052400	16	0035	SEA CALM; SOME IM
11053222	17	0253	SEA CALM; SMALL ICE FLOES
11054000	18	0038	SEA CALM; ICE STANDING OFF
11054800	19	0040	SEA CALM; BARRIER UNDERCUT
11055200	19	1241	SEA CALM; ICE VISIBLE IN THE DISTANCE
11055406	19	1919	HIGH FREEBOARD FLOE NEAR
11055606	20	0119	ICE INVASION; 1ST YEAR ICE MOVES S
11060202	20	1856	1ST YEAR ICE MOVES S
11060400	21	0044	IC DECREASES
11061200	22	0046	FLOES NOT MOVING; IC=8
11062000	23	0048	SEA CALM; IC=2; ICE STANDS OFF
11062729	24	0049	SEA CALM; LITTLE ACTIVITY
11063024	24	0919	RUBBLE PILE MOVES IN AND GROUNDS
11063625	25	0327	RUBBLE PILE BREAKS FREE & MOVES S
11064400	26	0053	MORE ICE GROUNDS; SEA CALM
11065124	27	0024	MORE RUBBLE MOVES IN
11070000	28	0057	RUBBLE REMAINS GROUNDED
11070800	29	0059	SEA CALM; IC=4
11071600	30	0101	SEA CALM; NO ACTIVITY
11072400	31	0103	SEA CALM; BARRIER UNDERCUT
11072919	31	1820	EDGE OF BARRIER BREAKS OFF

CAMERA 6' AZIMUTH 173° ELEVATION 20' AUGUST 1985

FRAME NUMBER	DATE	TIME (AST)	COMMENTS
11073200	1	0104	SEA CALM ICE BLOCKS RESTING ON SUBM BARRIER
11074000	2	0106	SEA CALM; IC=0
11074120	2	0611	LARGE PIECE BREAKS OFF; WATER JET IS APPARENT CAUSE
11074206	2	0744	WATER JET ON
11074217	2	0852	WATER JET STOPS
11080110	4	1713	BARRIER CALVES
11080126	4	1853	BARRIER BREAKS OFF AND FLOATS AWAY; SEA CALM
11080321	5	0022	BARRIER BREAKS UP; SEAS INCREASING
11080500	5	0412	LAST SEGMENT OF BARRIER IN FIELD BREAKS AWAY
11080722	5	1229	END OF FILM REEL
09001724	6	1637	NEW FILM REEL INSTALLED
09001800	6	1709	ICE RUBBLE BETWEEN CIDS & BARRIER
09004015	9	1250	RUBBLE MOVES OUT; SEA CALM
09005917	11	2210	LITTLE CHANGE
09011627	14	0219	ICE FLOES MOVE IN
09014126	17	0522	GENERALLY NO CHANGE